■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

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Of Interest to Managers

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Quarterly Highlights

IEP Bay Delta and Tributaries Database Interface. Chris Fox (DFG, pg. 3) describes ongoing efforts to create a sophisticated, user-friendly interface to extract data from the many databases managed by IEP.

Yolo Bypass Study. Bill Harrell, Ted Sommer, and Peggy Lehman (DWR, pg.3) summarize some of their Yolo Bypass work during the unusual hydrology of winter and spring 2003. Highlights of the year included the best floodplain splittail production in the past five years.

Fish Bulletin 250. Leslie Pierce (DWR, pg. 4) notes that the final draft of Bulletin 250 has been released. The summary of fish passage problems and restoration projects in Central and Northern California is the first new bulletin prepared by DWR in the past ten years.

Contributed Papers

Salinity and Temperature Monitoring in San Francisco Estuary: Lee Bergfeld and Dave Schoellhamer (USGS, pg. 5) report that the existing network of fixed continuous monitoring stations located around the perimeter of San Francisco Bay appears to be reasonably representative of salinities and temperatures throughout the expanse of the estuary including deep channel regions.

Deep Water Ship Channel Dissolved Oxygen Study: G. Fred Lee and Anne Jones-Lee (G. Fred Lee and Assoc. pg. 12) summarize a CALFED-funded review they have completed of 1999-2003 studies on the low-dissolved oxygen problem in San Joaquin River's Deep Water Ship Channel. Their review describes the current understanding of the factors that cause the DO problems, and some possible management approaches.

Environmental Monitoring Program Review: Zach Hymanson and Anke Mueller-Solger (CBDA and DWR, pg. 15) describe the recently completed IEP review of the Environmental Monitoring Program. The article provides insight into some of the staff and time requirements for the review, as well as major obstacles. Their valuable experience may help to guide future reviews of other programs, which IEP requires every five years.

California Bay-Delta Authority Activities

Kristen Honey and Zach Hymanson (CBDA, pg.24) give a brief summary of a CBDA Science Program symposium to review biological information related to the proposed long-term operations (OCAP[1]) of the CVP and SWP. The presentations at the workshop indicate that there has been significant progress in our understanding of the Delta and upstream regions over the past decade.

IEP Bibliography

Linda Rivard and Ted Sommer (DWR, pg. 28) have compiled the first-ever bibliography of IEP journal articles and books. The lengthy bibliography lists 191 papers in the open literature that have been produced using substantial IEP resources, samples, or data. The list is intended as a "track record" of IEP's progress, and as a reference list for the some of the major scientific issues and findings for the San Francisco Estuary.

1. Operating Criteria and Plan

IEP Quarterly Highlights

April-June 2003

Developing the New Bay Delta and Tributaries Database Interface

Chris Fox (DWR), cfox@water.ca.gov

The Bay Delta and Tributaries (BDAT) database merges data from dozens of smaller databases maintained by various agencies and other groups monitoring the environmental health of the waters of the San Francisco Bay-Delta and their tributaries. Once the data on water quality, hydrodynamics, and the abundance of fish, phytoplankton, and benthic organisms is merged, it is made available on the Internet.

By May 2002, it was recognized that the old "DBI map" (http://sarabande.water.ca.gov:8000/~bdtdb/), used to query the data in BDAT, needed to be replaced. We had a meeting in June 2002 with a number of data providers and users from different agencies to share and gather ideas for the new website. Common complaints included not knowing what is available in the database and difficulty getting data out. Marc Vayssières and Chris Fox used the notes from the meeting to initiate the design of the new database interface.

Karl Jacob's group initiated work on the technical side of the database interface according to specifications developed from the meeting.

Kris Lightsey began implementing the new database interface in January 2003. Karl Jacobs and Catalina Guillen wrote up database routines that create the datamarts in the database that support the background work of the interface. Many graphics had to be created to allow the database interface to resize on different monitor resolutions, so Brad Tom came up with a clever way to automate the graphics resizing.

By the 2003 IEP Conference in Monterey, the database interface was far enough along for us to give a presentation at the poster session. A number of people viewed and tried the database interface, and gave us additional comments and suggestions.

One of the biggest obstacles in this project was selecting, purchasing, and setting up the hardware and software needed. We needed a new machine to act as a server that was not only a dedicated machine, but one that had the capacity to run the Web server and the database engine. Steve Ehrhardt was the systems administrator who provided recommendations on hardware components needed, and performed the setup and security of the new system.

The new system's features include a large number of data summaries, so users can see the extent of data available in the database. The query process is designed to be simple and flexible to use. A separate section was added so that data that is considered sensitive by the data providers can only be viewed by users with a password. Several people from different agencies have volunteered to be beta testers, and will be testing it this summer. The data interface will be available to the public by the end of 2003 after comments and suggestions from the beta testers are incorporated into project improvements. We look forward to working with IEP and other Bay-Delta groups on further improving the new database interface. If you would like to review the new interface, please contact Kris Lightsey (klightse@water.ca.gov) or Chris Fox (cfox@water.ca.gov).

Yolo Bypass Study

Bill Harrell, Ted Sommer, and Peggy Lehman (DWR), bharrell@water.ca.gov

The Yolo Bypass program continued this year with a suite of sampling methods designed to monitor adult, juvenile, and larval fish; drift invertebrates; zooplankton; and chlorophyll. Hydrology in the floodplain was unique this year, with an early series of storms (late December 2002–January 2003) causing substantial inundation of the floodplain. This was followed by a relatively dry period until late May and early June when another series of storms caused spring inundation of the floodplain.

As in the previous few years, we operated a rotary screw trap and conducted beach seine hauls in winter and spring. Chinook salmon were the dominant native fish collected in February and March (n=531), with splittail becoming the most dominant in May and June (n>2,400). Splittail production appears to be substantially higher than 1999-2002, but not as high as the record year class in 1998. Splittail samples were collected for a companion study by Dr. Bernie May (UCD), who is evaluating the genetics of this species in different regions of the estuary. The samples will be shared by Fred Feyrer (DWR) for an IEP study of juvenile splittail growth and feeding success.

Season highlights from our fyke trap, which traps larger adult fish, include: 108 adult splittail in January through March; 83 adult white sturgeon in February through April; and 21 adult American shad in May and June. The high catch of white sturgeon was unusual compared to our previous years' sampling when numbers have not exceeded 35. The adult striped bass catch was near average at 204. Fisheries sampling for this season will be completed on June 30, 2003.

An additional study element was added this year to conduct a demonstration-scale project based on managed Yolo Bypass flooding for splittail and other aquatic species. The new element was an expansion of a small scale (0.1 ha) study, which demonstrated that splittail will spawn in a dry year if they are provided with suitable habitat. This study was to be conducted in a 19 ha floodplain wetland at the Yolo Bypass Wildlife Area. Unfortunately, hydrologic conditions caused failure of the small levee surrounding our study area, so the experiment for this season had to be aborted.

Zooplankton, drift invertebrate, and chlorophyll sampling continued as part of baseline food web monitoring. Fluorometry and grab samples demonstrate that Yolo Bypass chlorophyll levels were much higher that the adjacent Sacramento River, particularly during descending hydrographs. A new program element was added this year to measure carbon production rate in the Yolo Bypass. The objective of this study element is to measure the net plankton community carbon production and respiration rate of the Yolo Bypass and the adjacent Sacramento River channel during different hydrologies. The data will provide information on the potential net export of carbon from each habitat to the downstream estuarine food web. Sampling for these elements is complete and data analysis will be completed this fall.

Bulletin 250 – Fish Passage Improvement

Leslie Pierce (DWR), lpierce@water.ca.gov

The California Department of Water Resources (DWR) released a final draft of Bulletin 250, Fish Passage Improvement, on June 3 for public review. The bulletin has two important "firsts". It's the first new bulletin prepared by DWR in 10 years, and it's also the first time the directors of DWR and Department of Fish and Game (DFG) both signed the foreword of a DWR bulletin.

The co-signing of the foreword by DFG Director Robert Hight and DWR Director Thomas Hannigan exemplifies the commitment of staff from both agencies to coordinate and collaborate on fish passage issues of concern to the state and to the California Bay-Delta Authority (CBDA). The information in the bulletin can be used to identify fish passage issues and can guide agency efforts to improve fish passage, while meeting the goals of CBDA's Ecosystem Restoration Program.

Bulletin 250 focuses on the challenges, opportunities, successes, and problems of fish passage in Central and Northern California watersheds. The purposes of the bulletin are:

- To identify potential man-made barriers to anadromous fish migration below the major flood control and water supply reservoirs within the Ecosystem Restoration Program study area, the Bay Area, and the San Joaquin River south to the Kings River;
- To outline criteria developed to prioritize barrier solution projects; and
- To describe efforts under way by the Fish Passage Improvement Program and other agencies to solve problems posed by fish migration barriers.

The comment period ended on August 1, but you can still view the document on the Internet at http:// www.isi.water.ca.gov/fish/b250.shtml. Comments will be used to revise the bulletin. A final bulletin should be completed by the end of the year.

If you have questions about Bulletin 250 or about the Fish Passage Improvement Program, please contact Leslie Pierce at (916) 651-9630 or at lpierce@water.ca.gov.

CONTRIBUTED PAPERS

Comparison of Salinity and Temperature at Continuous Monitoring Stations and Nearby Monthly Measurement Sites in San Francisco Bay

Lee G. Bergfeld and David H. Schoellhamer (US Geological Survey), dschoell@usgs.gov

Introduction

Salinity and temperature are crucial state variables affecting estuarine habitat and, thus, are measured by various San Francisco Estuary programs. This article presents a comparison of salinity and temperature data collected at seven continuous monitoring stations throughout San Francisco Bay (Figure 1) with data collected monthly by the US Geological Survey (USGS) research vessel (*RV*) *Polaris*. The data comparison was done to determine if the continuous monitoring stations, which mostly are located near shore and always on structures in the water, are representative of water conditions in the main channel of the estuary where the *RV Polaris* collects measurements.

Methods

The USGS continuous monitoring stations measure conductivity and temperature at two depths in the water column: near the surface and the bottom (Buchanan, 2002). Conductivity is converted to salinity according to the practical salinity scale (Fofonoff and Millard 1983; Hill and others 1986). The USGS stations are equipped with Foxboro[1] conductivity sensors and Campbell Scientific temperature sensors, with the exception of Carquinez Bridge, which is equipped with two Hydrolab DS-4 conductivity and temperature instruments. The sensors are positioned near the surface and the bottom in the water column on a suspension line attached to an anchor weight, which allows the sensors to be raised and lowered easily for servicing. An electronic data logger controls data acquisition, data storage, and sensor timing. The logger is programmed to activate the sensor every 15 minutes, collect data each second for 1 minute, and then average and store the output for that 1-minute period. Site visits to clean and calibrate the sensors operated by the USGS are made every 14-21 days. This analysis includes stations at Benicia Bridge, Carquinez Bridge, Point San Pablo, San Francisco Pier 24, and San Mateo Bridge. Additional USGS continuous monitoring stations (not shown in Figure 1) are located at San Francisco Presidio, Napa River at Mare Island Causeway, and San Pablo Bay Channel Marker 9, but they are too far from *RV Polaris* measurement sites to be used in this analysis. The USGS continuous monitoring station data are available at http://sfports.wr.usgs.gov/Fixed_sta/.

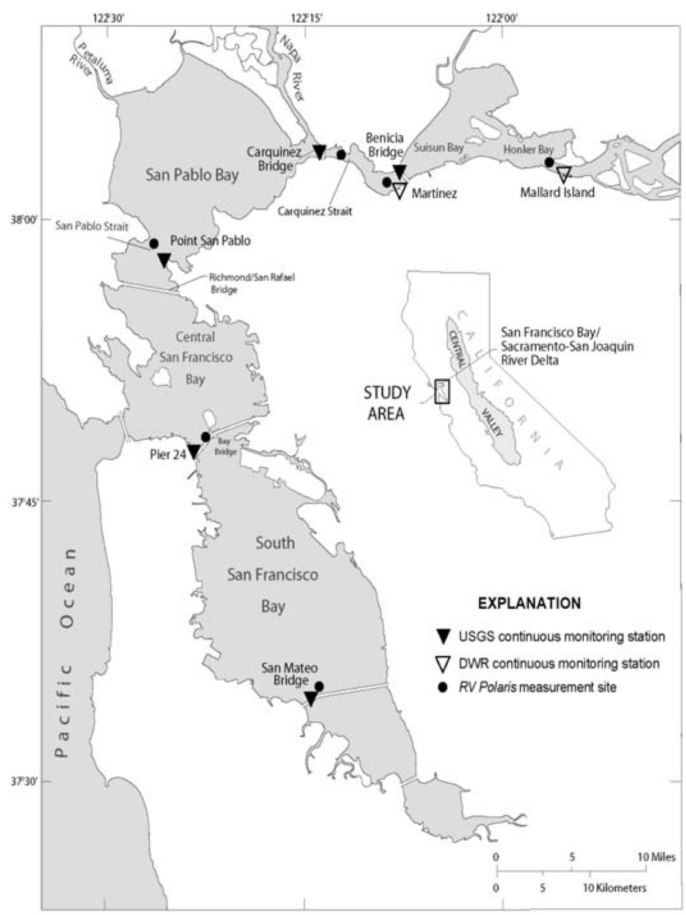

Figure 1 San Francisco Bay study area.

1. The use of firm, trade, and brand names in this article is for identification purposes only and does not constitute endorsement by the US Geological Survey.

Data from continuous monitoring stations operated by the Department of Water Resources (DWR) at Mallard Island and Martinez were included in this analysis. At these stations, conductivity and temperature are measured 1 meter (m) below the water surface and conductivity is measured 1.52 m above the bottom (http://iep.water.ca.gov/metadata/HEC-DSS/DWR/ESO/D1485Cont.metafile.htm). Near-surface water is collected continuously by pumps and analyzed by Schneider Instruments continuous water-quality monitors that sample three times per second. Data are averaged and stored every 60 minutes. Bottom conductivity is measured using Foxboro model 872 Electrochemical Monitors and the outputs are recorded and stored every 15 minutes. Stations operated by DWR are cleaned and serviced every 10 to 14 days. The data used in this analysis are available from the Interagency Ecological Program at http://www.iep.ca.gov/dss/.

The *RV Polaris* cruises along the central, deep channel of the estuary measuring water quality monthly at 39 fixed locations, spaced approximately 6 kilometers (km) apart along the longitudinal axis (Arnsberg and others, 1998; http://sfbay.wr.usgs.gov/access/wqdata/overview). A submersible instrument package that measures conductivity, temperature, depth, and optical backscatterance (CTDO) is lowered into the water from the *RV Polaris*. A Sea-Bird Electronics-4 sensor measures conductivity and a Sea-Bird Electronics-3 thermistor measures temperature. The manufacturer calibrates both sensors at the start of each calendar year. The sensors record data 24 times per second as the package is lowered through the water column at a rate of approximately 1 m per second. The data, therefore, are collected every 4 centimeters from the water surface to the bottom. Recorded values are averaged over 1 m and reported in 1-meter bins. Reported values for meter *n* below the water surface represent the mean value from *n* - 0.5m to *n* + 0.5m. *RV Polaris* data used in this analysis were downloaded from the USGS online database at http://sfbay.wr.usgs.gov/access/wqdata/query/.

Using the locations, dates, and times of the nearest *RV Polaris* data, the corresponding data values were retrieved from the time-series record at the continuous monitoring stations (Table 1). Time periods for the compared measurements varied by site, depending on when the stations were in service. Data from the continuous stations are incomplete due to biological fouling of instruments, instrument malfunction, and temporary closures for bridge construction. The USGS continuous monitoring stations and the DWR near-bottom conductivity stations collect data every fifteen minutes, therefore, the maximum difference in time between compared measurements is approximately 7.5 minutes. The DWR near-surface stations collect data every 60 minutes; therefore, the maximum difference in time between compared measurements is 30 minutes.

Table 1 Physical characteristics of the continuous monitoring stations and the *RV Polaris* sampling sites.

Continuous Monitoring Station	*Total water depth at continuous station (m)*	*Sensor position*	*Elevation of sensor above bottom (m)*	*Nearest* RV Polaris *site Number*	*Total water depth at* RV Polaris *site (m)*	*Distance between measurements (km)*	*Comparison Start Date*	*Comparison End Date*
Mallard Island	7.6	NB	1.5	4	11.6	1.48	September 11, 1996	July 17, 2001
		NS	* 1				January 31, 1989	November 27, 2001
Benicia Bridge	24.4	NB	7.6	8	14.3	2.83	January 6, 1998	September 11, 2001
		NS	22.6				November 6, 1997	September 11, 2001
Martinez	9.4	NB	1.5	8	14.3	1.21	July 28, 1994	November 27, 2001
		NS	* 1				July 28, 1994	November 27, 2001
Carquinez Bridge	26.8	NB	4.9	10	17.7	2.02	June 7, 1999	September 5, 2000
		NS	17.7				November 10, 1998	September 5, 2000
Point San Pablo	7.9	NB	1.8	15	22.9	1.36	December 6, 1990	September 5, 2000
		NS	6.7				December 6, 1990	September 5, 2000
Pier 24	12.5	NB	3.4	21	17.4	2.33	December 7, 1990	September 7, 2000
		NS	9.8				December 7, 1990	September 7, 2000
San Mateo Bridge	14.6	NB	3.1	29	14.6	0.65	December 7, 1990	September 7, 2000
		NS	13.6				December 7, 1990	September 7, 2000

NB: near bottom; NS: near surface; m: meter; km: kilometer; *: distance from surface. Total water depth is relative to mean lower low water (MLLW)

The *RV Polaris* vertical bin that corresponds to the elevation of a continuous sensor was determined by calculating the distance from the water surface to the sensor

$$d_{ss} = d_{mx} - MLLW_{Polaris} + MLLW_{fixed} - z_i \quad (1)$$

in which the variables are defined in Figure 2. The USGS operates a water level recorder at Point San Pablo where

$$d_{ss} = h_{PSP} + MLLW_{fixed} - z_i \quad (2)$$

in which h_{PSP} is the measured elevation of the water surface above mean lower low water. Equation 2 is more accurate than equation 1 because the only measurement of water depth at the time of the *RV Polaris* measurement (d_{mx}) is the deepest recorded CTDO bin, which may underestimate the water depth by as much as 1.5 m and is reported only to within 1 m (one bin). In addition, if the *RV Polaris* was not positioned exactly at the sampling site, then the assumed MLLW depth at the site may be inaccurate. The results of equation 1 were compared against those of equation 2 at Point San Pablo. For the near-bottom sensor, equation 1 was within 2 m (two bins) of equation 2 for 90% of the measurements, and for the near-bottom sensor, equation 1 was within 2 m of equation 2 for 60% of the measurements.

Once the continuous and monthly *RV Polaris* data sets were aligned temporally and spatially, they were compared using two methods of linear regression. The first method was a simple linear regression, or least-squares method (Helsel and Hirsch, 1992). The second method was the repeated median method, which has the advantage of being less influenced by outliers and is applicable to cases where the variance of the dependent variable (Y) is not constant as the independent variable (X) varies (Helsel and Hirsch, 1992; Siegel, 1982). The repeated median method is a robust, nonparametric method that calculates the slopes in a two-part process (Buchanan and Ganju, 2002). First, for each point (X,Y) the median of all possible “point i” to “point j” slopes:

$$m_i = median\frac{(Y_j - Y_i)}{(X_j - X_i)} \qquad \text{for all } j \neq i \quad (3)$$

The slope of the best-fit line, m_{rm}, then is determined as the median of all possible slopes calculated above:

$$m_{rm} = median(m_i) \qquad \text{for all } i \quad (4)$$

The y-intercept of the best-fit line, b_{rm}, is the median value of all possible y-intercept values using the possible slopes calculated above:

$$b_{rm} = median(Y_i - m_{rm}X_i) \qquad \text{for all } i \quad (5)$$

The final form of the equation thus becomes:

$$Y = m_{rm}X + b_{rm} \quad (6)$$

For both methods the continuous station data were plotted as the independent (x-axis) variable and the *RV Polaris* data as the dependent (y-axis) variable. Values reported for the least-squares (*ls*) and repeated median (*rm*) methods include the slope (m_{ls} and m_{rm}) and y-intercept (b_{ls} and b_{rm}). Additional values for the least-squares method of regression are the coefficient of determination (r^2_{ls}), a measure of the strength of association between the two data points with $r^2_{ls} = 1$ being perfect correlation, and the significance level (p_{ls}) or the probability of there being no linear relation between the data sets (Helsel and Hirsch, 1992). The mean difference and root-mean-squared (RMS) difference were calculated to evaluate the differences between the data sets. The mean difference:

$$RMS_{diff} = \sqrt{\frac{1}{n}\sum_{1}^{n}(C_i - P_i)^2} \quad (7)$$

in which n is the number of data points compared, C_i is the continuous monitoring station data sample i, and P_i is the *RV Polaris* data sample i.

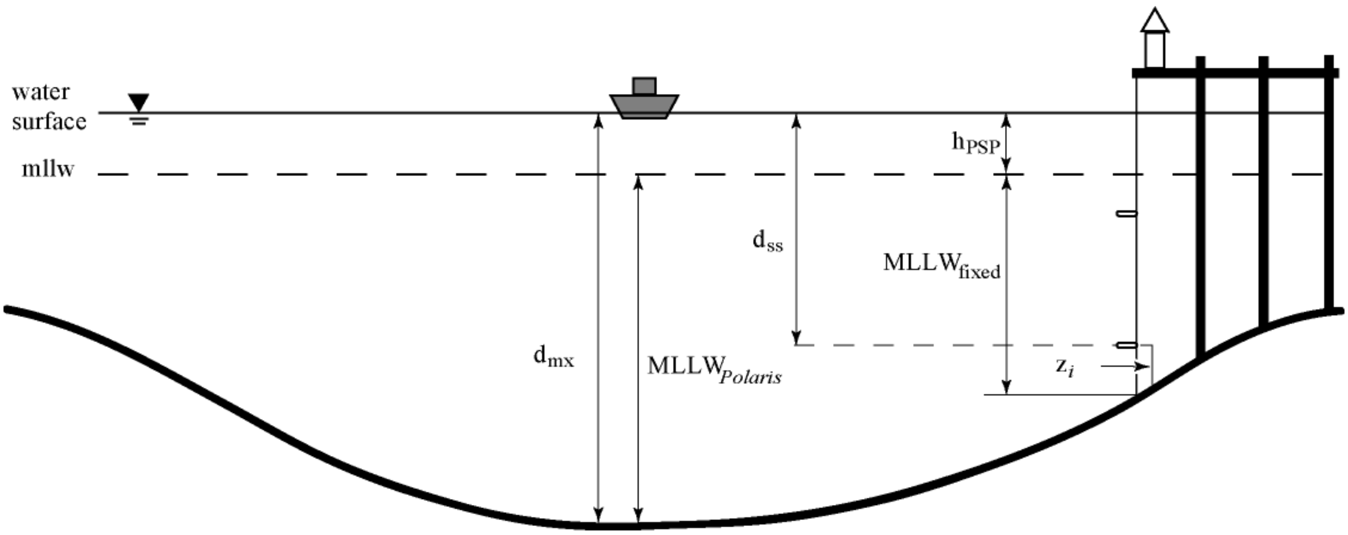

Figure 2 Variables used to calculate the distance from the water surface to a fixed sensor d_{ss}.

The mean difference is used to show either a trend of the continuous monitoring station measuring higher values (a positive mean difference) or a trend of the *RV Polaris* measuring higher values (a negative mean difference). The RMS difference

$$RMS_{diff} = \sqrt{\frac{1}{n}\sum_{1}^{n}(C_i - P_i)^2} \tag{8}$$

The RMS_{diff} is the more robust of the two methods for determining error in the data sets because positive and negative values for C_i-P_i do not counteract each other and reduce the overall value. A slope (*m*) of 1, a y-intercept (*b*) of 0, and $\overline{diff}$ and RMS_{diff} of 0 represent a perfect linear relation between the two sampling sites for both regression methods.

Results

The results of each statistical method are reported in Table 2. Figures 3-6 are representative of the salinity and temperature comparisons for the seven sites and show the slight difference between the two regression methods.

Discussion and Conclusion

The regressions show a strong linear relation between the continuous monitoring stations and the *RV Polaris* sites for temperature and salinity. The coefficient of determination from the least squares method for all of the temperature stations demonstrate a strong correlation between the two sites with $r^2_{ls} > 0.95$. Linear regression slopes were near one (mean 1.02, range 0.943 to 1.13) and y-intercepts were near zero (mean -0.098 ^oC, range -1.2 to 0.9 ^oC). Salinity data showed slightly more variance, though the correlations are still very strong with $r^2_{ls} >0.86$. The salinity linear regression slopes were near one (mean 1.03, range 0.869 to 1.29) and y-intercepts were near zero (mean 0.219, range -2.12 to 3.57). All least-squares method temperature and salinity linear regressions were significant at the p_{ls} <0.001 level.

The mean differences in the measurements (Table 2) are consistent with the relative locations of the paired measurement stations and river-to-ocean gradients of salinity and temperature. For comparisons made in the Suisun, San Pablo, and Central bays, the station closer to the Pacific Ocean had greater salinity and lower temperature than the station closer to the Sacramento-San Joaquin River Delta. The locations where the paired measurements were collected differ by as much as 2.8 km. Even though the typical error in selecting the appropriate *RV Polaris* vertical bin for the comparison typically is one or two bins (meters), this error is not large enough to mask the expected river-to-ocean gradients of salinity and temperature.

Table 2 Statistical results of linear regressions for least-squares and repeated median methods and error measurements.

Continuous Monitoring Station	*Variable*	*Location*	*Number of points*	m_{ls}	b_{ls}	r^2_{ls}	m_{rm}	b_{rm}	$\overline{diff}$	RMS_{diff}
Mallard Island	Sal	NB	39	1.15	0.177	0.986	1.24	0.0	-0.602	0.886
		NS	116	1.01	0.108	0.972	1.06	0.0	-0.148	0.526
	Temp	NS	117	1.02	-0.472	0.995	1.01	0.4	0.191	0.390
Benicia Bridge	Sal	NB	7	0.949	2.83	0.986	0.967	2.8	-2.26	2.38
		NS	8	1.20	0.0418	0.988	1.10	0	-0.703	1.22
	Temp	NB	11	0.949	0.679	0.998	0.943	0.9	0.154	0.314
		NS	10	0.985	0.177	0.994	0.966	0.4	0.066	0.358
Martinez	Sal	NB	55	1.03	0.504	0.988	1.04	0.3	-0.818	1.15
		NS	60	1.06	0.303	0.940	1.04	0.0	-0.762	1.87
	Temp	NS	66	0.992	0.002	0.985	0.996	0.0	0.131	0.518
Carquinez Bridge	Sal	NB	11	1.10	-1.62	0.941	1.06	-0.9	-0.132	0.968
		NS	11	1.07	-2.12	0.861	0.869	0.8	1.12	2.54
	Temp	NB	11	1.01	-0.180	0.998	1.01	-0.2	-0.023	0.153
		NS	11	1.03	-0.442	0.998	1.03	-0.4	-0.047	0.209
Point San Pablo	Sal	NB	97	0.961	0.767	0.937	0.967	0.4	0.0980	1.79
		NS	94	1.01	-1.49	0.923	1.01	-1.4	1.24	2.62
	Temp	NB	102	0.996	0.215	0.982	1.02	-0.1	-0.155	0.437
		NS	101	1.04	-0.387	0.979	1.06	-0.6	-0.281	0.586
Pier 24	Sal	NB	133	0.875	3.57	0.898	0.982	0.4	-0.337	1.73
		NS	140	0.954	0.981	0.937	1.00	-0.3	0.185	1.50
	Temp	NB	141	1.08	-0.679	0.950	1.09	-0.8	-0.461	0.732
		NS	142	1.12	-1.10	0.957	1.13	-1.2	-0.563	0.822
San Mateo Bridge	Sal	NB	175	0.989	0.593	0.995	0.998	0.3	-0.325	0.505
		NS	159	1.09	-0.11	0.985	1.12	-0.8	-1.83	2.03
	Temp	NB	179	0.977	0.462	0.996	0.975	0.5	-0.100	0.258
		NS	185	0.987	0.266	0.996	0.992	0.2	-0.063	0.238

Values shown are dimensionless except y-intercepts and differences for temperature which are in degrees Celsius. $p_{ls}<0.001$ for all regressions. m_{ls}, slope from least-squares method; b_{ls}, y-intercept from least-squares method; r^2_{ls}, coefficient of determination for the least-squares method; m_{rm}, slope from repeated median method. b_{rm}, y-intercept from repeated median method. $\overline{diff}$, mean difference; RMS_{diff}, root-mean-squared difference

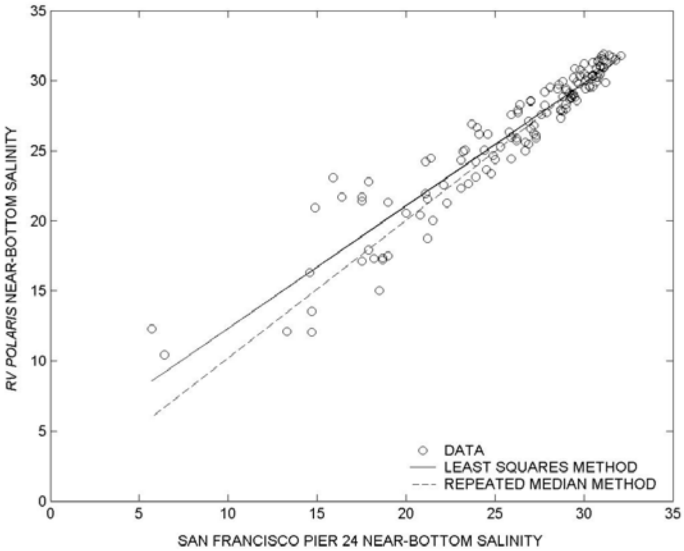

Figure 3 Comparison of near-bottom salinity measurements at the San Francisco Pier 24 continuous monitoring station and during monthly cruises by *RV Polaris* at station 21.

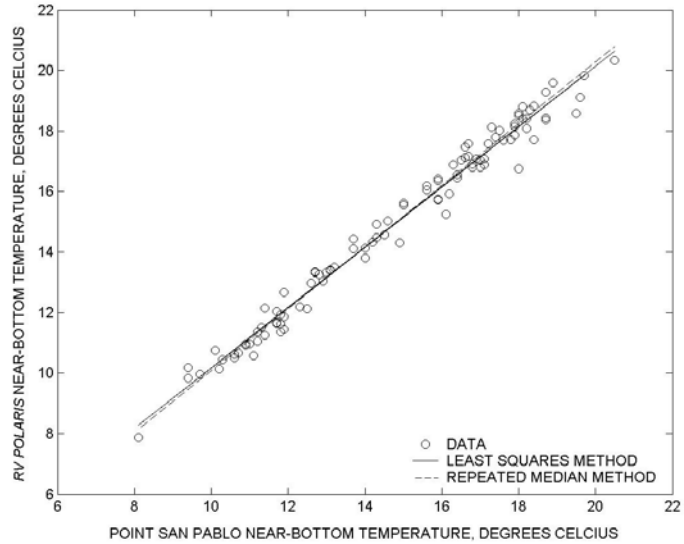

Figure 5 Comparison of near-bottom temperature measurements at the Point San Pablo monitoring station and during monthly cruises by *RV Polaris* at station 15.

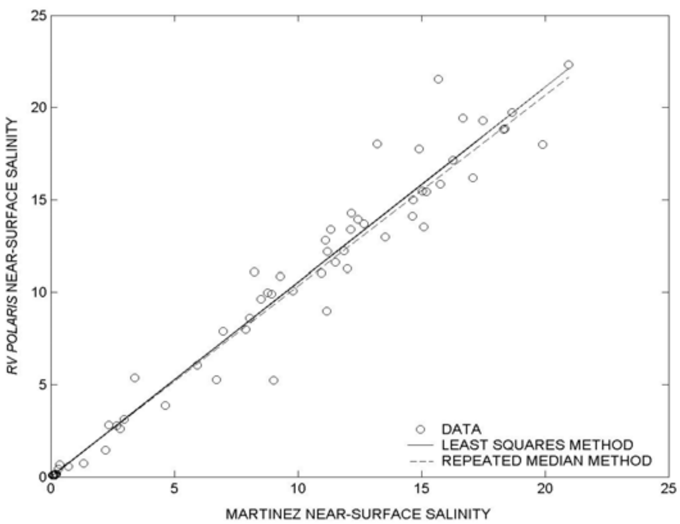

Figure 4 Comparison of near-surface salinity measurements at the Martinez continuous monitoring station and during monthly cruises by *RV Polaris* at station 8.

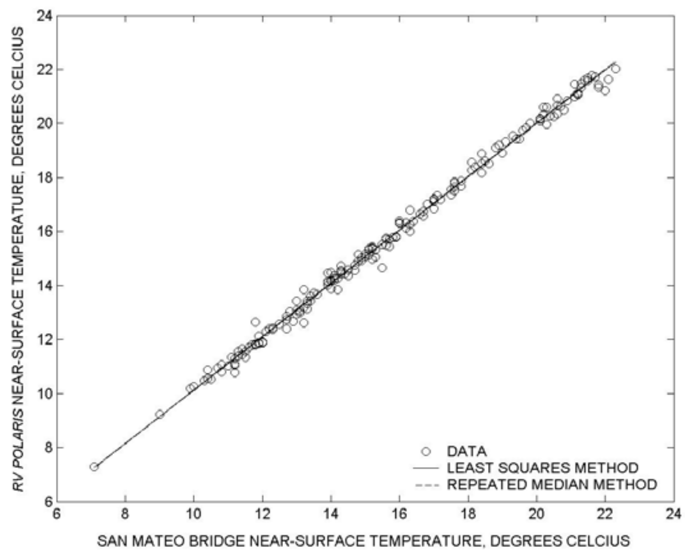

Figure 6 Comparison of near-surface temperature measurements at the San Mateo Bridge continuous monitoring station and during monthly cruises by *RV Polaris* at station 29.

As the distance between station pairs increases, one would expect that RMS_{diff} would increase, but this is not the case for these data. RMS_{diff} is not related to distance between station pairs (not shown). For example, Benicia Bridge and Martinez are both compared to the same *RV Polaris* sampling location. Benicia Bridge is 1.6 km farther from the *RV Polaris* sampling location, but the RMS_{diff} is less for two of the three variables (near-surface salinity and temperature but not near-bottom salinity, Table 2). Because there is no Bay-wide relation between RMS_{diff} and distance between sampling stations, RMS_{diff} probably is determined by local mixing and spatial variability between the paired sampling stations. The Martinez station is located on the south shore of Carquinez Strait but the Benicia Bridge station is located in the deep channel and, therefore, may be more representative of conditions at the *RV Polaris* sampling station in the deep channel, despite being further away. Differences in the elevation and timing of the paired measurements, and bias in the direction and timing of the *RV Polaris* cruises relative to tides (Schoellhamer 2001a and 2001b), also may contribute to differences between the continuous and *RV Polaris* data.

The strength of linear regressions and the physically reasonable and consistent differences in the data show that the continuous monitoring stations are representative of the salinity and temperature in the main channel of the estuary. Measurement differences are consistent and physically reasonable when the relative location of paired measurement stations is considered in relation to salinity and temperature gradients in the estuary. Local spatial variability is the likely primary factor creating discrepancies of salinity and temperature.

Acknowledgments

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Update on the Understanding of the Low-DO Problem in the San Joaquin River's Deep Water Ship Channel

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The Winter 2001 IEP Newsletter contained an article by Lee and Jones-Lee (2001) describing some of the major issues in developing the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) Dissolved Oxygen (DO) TMDL. The following is a brief summary of some of the major findings from a CALFED-funded review of 1999-2003 studies (Lee and Jones-Lee 2003). Additional information is provided on the SJR DO TMDL website at http://www.sjrtmdl.org, and on http://www.gfredlee.com in the San Joaquin River watershed section.

DO Depletion in the DWSC

California Department of Water Resources (DWR) described the occurrence of low DO in the SJR DWSC (Figure 1) based on the monitoring cruises conducted during the late summer and fall of each year (Ralston and Hayes, 2002). Lee and Jones-Lee (2003) have summarized the DWR cruise data from 1995 through 2002. Dissolved oxygen concentrations in the DWSC water column from just downstream of the Port to, at times, as far as Columbia Cut, are depleted at times one to several mg/L below the water quality objective of 5 mg/L during the summer through August, and 6 mg/L from September through November.

Under low SJR DWSC flow conditions of a few hundred cfs, the DO concentrations in the DWSC waters can be as low as about 1 to 2 mg/L. The DO concentrations near the bottom of the DWSC are sometimes 1 to 2 mg/L lower than those found in the surface waters. This difference is not due to thermal stratification within the DWSC, but is related to inadequate vertical mixing of the water column by tidal currents "coupled with" algal photosynthesis in the near-surface waters and suspended particulate biochemical oxygen demand (BOD) in the near-bottom waters.

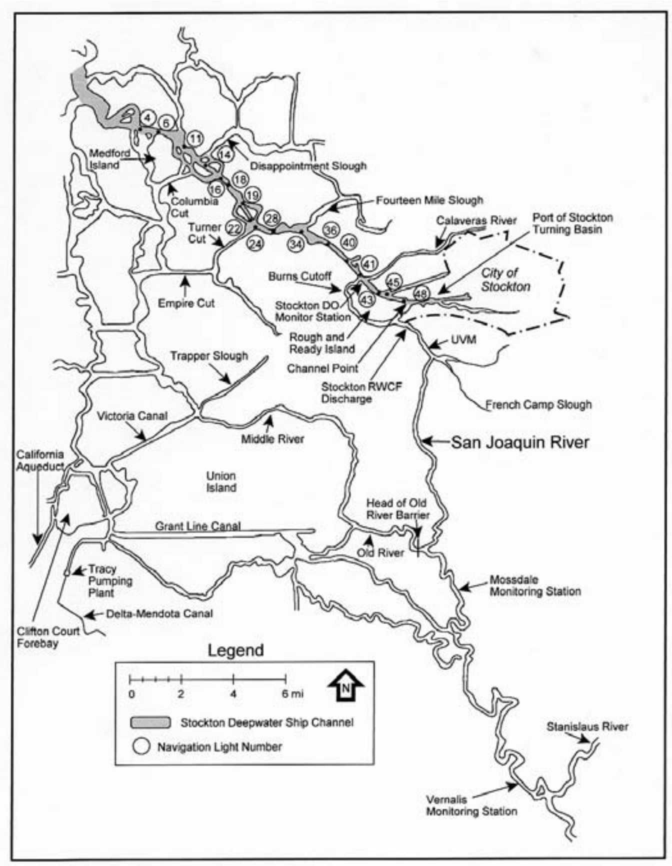

Figure 1 **Map of the Lower SJR and DWSC Study Area**

Constituents Responsible for Oxygen Depletion

The depletion of DO below the water quality objective is caused by carbonaceous biochemical oxygen demand (CBOD) and nitrogenous BOD (NBOD). The CBOD occurs primary in the form of algae. The NBOD is composed of ammonia and organic nitrogen that is mineralized to ammonia, which is biochemically oxidized to nitrite and nitrate (nitrification). The city of Stockton discharges its treated domestic wastewaters to the SJR approximately 2 miles upstream of where the SJR enters the DWSC at Channel Point. At times, especially during high ammonia concentrations in the wastewater effluent and low SJR DWSC flows, the city's wastewater effluent can contribute over 80% of the total oxygen demand load to the DWSC. At other times, the city's contribution to the oxygen demand load can be on the order of 10 to 20% of the total oxygen demand load to the DWSC.

The primary source of carbonaceous and, to some extent nitrogenous, oxygen demand for the DWSC occurs in the form of algae that develop in the SJR upstream of the DWSC. At times the upstream oxygen demand loads represent on the order of 90% of the total oxygen demand load to the DWSC. The relative proportion of the city of Stockton and upstream algal oxygen demand loads is variable, dependent on the city's wastewater effluent ammonia concentrations, the planktonic algal concentrations in the SJR that are discharged to the DWSC, and the flow of the SJR through the DWSC.

Factors Influencing DO Depletion in the DWSC

There are a number of factors that have been found to influence the DO depletion in the DWSC for a given oxygen demand load. These include the following:

- ***Port of Stockton.*** The development of the DWSC to the Port of Stockton greatly reduced the oxygen demand assimilative capacity of the SJR below the Port by transforming the channel from a shallow, rapidly moving water body to a long, thin lake, thereby increasing hydraulic residence time for BOD exertion. The former channel configuration would not have produced the current low-DO problems given similar inputs. The development of the Deep Water Ship Channel basically transformed the former undredged SJR channel through the Delta from a shallow, rapidly moving waterbody, to a long, thin, lake with a significantly increased hydraulic residence time for BOD exertion. It has been found that, if the Deep Water Ship Channel did not exist, there would be few, if any, low-DO problems in the channel.

- ***SJR Flow through the DWSC.*** The flow of the SJR through the DWSC influences DO depletion by affecting the hydraulic residence time (travel time) of oxygen demand loads through the critical reach. Under high flow conditions (> about 2,000 cfs), DO depletions below the water quality objective do not occur in the DWSC. SJR flows through the DWSC of a few hundred cfs lead to the greatest DO depletion below the water quality objective. The flow of the SJR through the DWSC influences the amount of upstream algal (oxygen demand) load that enters the DWSC, with greater oxygen demand loads occurring with higher flows. The magnitude of the oxygen deficit below the water quality objective is SJR DWSC flow-dependent.

- ***Sacramento River Cross Channel/Delta Flow.*** The export pumping of South Delta water by the state and federal projects to Central and Southern California creates a strong cross-Delta flow of Sacramento River water. This cross-Delta flow limits the downstream extent of DO depletion within the DWSC to upstream of Disappointment Slough/Columbia Cut.

- ***Growth of Algae within the DWSC.*** Appreciable algal growth occurs within the DWSC; however, this growth does not add to low-DO problems in the surface waters of the DWSC, since it is accompanied by photosynthetic oxygen production. The increased algal growth within the DWSC is likely causing increased DO depletion in the near-bottom waters of the DWSC, due to the settling and death of the DWSC-produced algae.

- ***Sediment Oxygen Demand (SOD).*** Measurements of the bedded sediment oxygen demand within the DWSC show that it tends to be somewhat lower than normal SOD for "polluted" waterbodies. However, the tidal velocities that occur within the DWSC have been found to be sufficient to suspend bedded sediments and to hinder the settling of particulate oxygen demand. This leads to an increased oxygen demand associated with particulates in the near-bottom waters of the DWSC.

- ***Atmospheric Aeration.*** Since the surface waters of the DWSC tend to be undersaturated with respect to dissolved oxygen, except possibly during late afternoon when intense photosynthesis is occurring in the surface waters, there is a net transfer of atmospheric oxygen to the DWSC through atmospheric surface aeration.

- ***Light Penetration.*** Secchi depths typically on the order of 1 to 2 ft are found in the SJR and in the DWSC during the summer and fall. This limits the photic zone (depth to which algal photosynthesis can occur) to about 6 ft. The inorganic turbidity derived from watershed erosion significantly reduces the depth of the photic zone, compared to photic zone depths that are found in most waterbodies where light penetration is controlled by light scattering and absorption by algae.

- ***Algal Nutrients.*** The concentrations of algal available nutrients (nitrate and soluble orthophosphate) within the SJR upstream of the DWSC and within the DWSC are at least 10 to 100 times surplus of those that are algal growth-rate-limiting. Algal growth within the SJR and DWSC appears to be controlled by light limitation.

- ***Temperature.*** Increases in temperature in the SJR and DWSC increase algal growth rates and rates of DO depletion reactions. Increased temperature also decreases the solubility of oxygen. Some of the year-to-year variations in DO depletion in the DWSC may be related to temperature differences, which influence algal growth in the SJR watershed and oxygen depletion within the DWSC.

A "Strawman" analysis of oxygen demand loads and impacts on DO depletions within the DWSC shows that the planktonic algal concentrations present in the SJR at Mossdale are related to the DO depletion at the DWR Rough and Ready Island (RRI) continuous monitoring station. High planktonic algal chlorophyll *a*, which is correlated to high BOD at Mossdale as well as upstream in the SJR, tended to be associated with the greatest DO depletion at the DWR RRI station.

Examination of the dissolved oxygen concentrations found in the DWSC at the RRI monitoring station shows that DO depletions below the water quality objective occur in the winter in some years. During 2002 and 2003, DO depletions at the RRI station occurred below the WQO during January, February, and/or March. In mid-February 2003, surface water DO levels of 0 mg/L were found at this station for several weeks. Further, there was a period in late January through early March 2003 when the surface water DOs at the RRI station were below 3 mg/L. The low-DO conditions found in late January through early March 2003 were related to city of Stockton wastewater ammonia discharges and low SJR DWSC flow.

During the low-DO period when there were low SJR flows through the DWSC, the SJR at Vernalis flows were in excess of 1,800 cfs, which means that the low SJR DWSC flows were due to diversion of most of the SJR flow at Vernalis into the South Delta for export to Central and Southern California. Without this diversion of SJR water into Old River, the extremely low DO that occurred in the winter of 2003 and at other times in 2002 would not have occurred since the hydraulic residence time of the DWSC would have been decreased to a few days from the over 30 days that occurred.

Oxygen Demand Loads

Box Model Load calculations were made for the 43 monitoring runs that the city of Stockton made during the summer/fall 1999, 2000, and 2001. Figure 2 presents a diagram of the three-year summer/fall average loads of oxygen demand in the SJR at Mossdale plus the city's oxygen demand wastewater loads, export of oxygen demand from the DWSC at Turner Cut and the magnitude of oxygen deficit below the water quality objective within the DWSC between Channel Point and Turner Cut.

Water quality monitoring and flow measurements of the SJR and tributaries enabled us to determine that the oxygen demand of water entering the DWSC was equivalent to the combined discharges of algae from Mud and Salt sloughs and the SJR upstream of their confluences.

The studies of the past four years plus other data have provided information that can be used to formulate a management plan to control the DO problem in the DWSC. Information on these issues is provided by Lee and Jones-Lee (2003). They include aeration of the Deep Water Ship Channel, control of the city of Stockton's wastewater effluent ammonia, and control of nutrients that lead to high algal growth in the Mud and Salt Slough and SJR upstream of Lander Avenue. Also, the potential for increasing the flow of the SJR through the DWSC to eliminate the long hydraulic residence times that are found under extremely low flow conditions is being evaluated. Further studies are needed to evaluate the potential efficacy of each of these approaches.

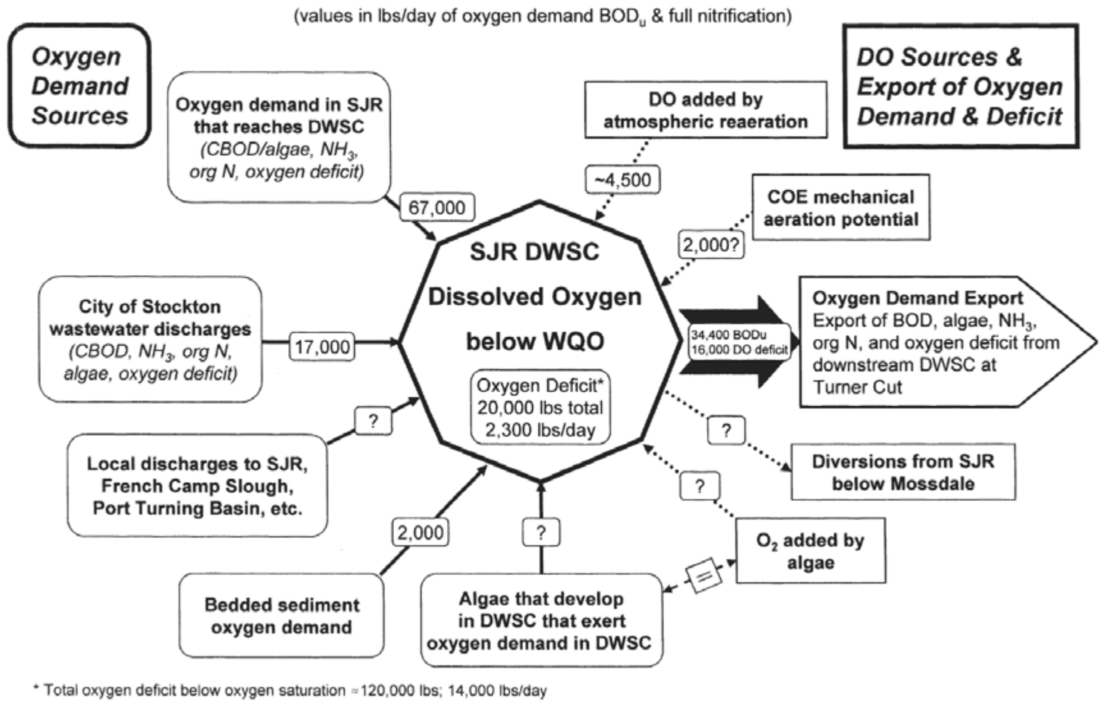

Figure 2 Box model of estimated DO sources/sinks in SJR DWSC (SJR DWSC Flow: 930 cfs; Travel Time: 8.6 days)

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Review of the Environmental Monitoring Program

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The Interagency Ecological Program (IEP) has a policy that requires review of each IEP monitoring program once every five years. The intent of this policy is to provide a means for considering the structure and function of ongoing, and in most cases longstanding, monitoring programs to ensure they remain relevant and effective. In 2001 the IEP requested a review of the Environmental Monitoring Program (EMP).

Although operated under the auspices of the IEP, the CA Department of Water Resources (DWR) and the US Bureau of Reclamation (USBR) are required to implement the EMP as a condition of CA State Water Resources Control Board (SWRCB) Water Right Decision 1641 (D-1641)[1]. This water right decision prescribes conditions that regulate operations of the State Water Project (SWP) and Central Valley Project (CVP). Under D-1641, a review of the EMP is required every three years with the first review due in December 2002. Thus, review of the EMP was intended to satisfy the requirements of the IEP and D-1641.

Review of a comprehensive monitoring program that spans four decades, has an annual operating budget of about $2 million, and employs about 20 staff from four different agencies is not a trivial matter. However, the EMP is fairly representative of the effort and resources the IEP dedicates to its monitoring programs, so the issues addressed in the EMP review reflect issues germane to the review of many IEP monitoring programs. In this article we describe the process used to complete a comprehensive programmatic review of the EMP. We describe the general features of the review and focus on the key elements of each feature. Several written documents were produced during the EMP review. Final versions of these documents along with other program information and EMP monitoring data are available at http://iep.water.ca.gov/emp.

I. EMP Background in Brief

The EMP was initiated in 1971 in compliance with SWRCB Water Right Decision 1379. Currently mandated by D-1641, the program is carried out jointly by the two water right permittees, DWR and USBR, with assistance from the CA Department of Fish and Game (DFG) and the US Geological Survey (USGS). The EMP is one of the oldest interagency monitoring programs operated under IEP.

The goals of the EMP given in D-1641 are to (1) ensure compliance with flow-related water quality objectives; (2) identify meaningful changes in any significant water quality parameters potentially related to operation of the SWP or the CVP; and (3) reveal trends in ecological changes potentially related to SWP/CVP operations. The EMP collects data on a wide range of physical, chemical, and biological constituents used to monitor the status and trends of environmental conditions in San Pablo Bay, Suisun Bay, and the Sacramento-San Joaquin Delta (collectively referred to as the upper San Francisco Estuary or upper estuary). Discrete water quality samples are collected once a month by boat or van at 11 stations located throughout the upper estuary. Several constituents are also monitored continuously at seven shore-based stations (Table 1). While some discrete sample analysis is completed in the field, most analyses are conducted by DWR's Bryte Chemical Laboratory (water chemistry and phytoplankton samples), DFG's laboratory in Stockton (zooplankton samples), and a contract laboratory (benthos samples). The resulting data are stored in the Bay-Delta Tributaries database and the DWR Water Data Library. Continuous data are available on a near real-time basis through the IEP Hydrologic Engineering Center Data Storage System (HEC-DSS) time-series database. Monitoring data are analyzed and summarized in annual and occasional multi-year reports, IEP Newsletter articles, IEP technical reports, and peer-reviewed journal articles.

1. California State Water Resources Control Board, Water Right Decision 1641, Revised March 15, 2000.

Table 1 A listing of the various subject areas considered part of the EMP and the frequency of sampling before and after the 1995 program review.

EMP Subject Area	*Sampling Frequency 1971-1995*	*Sampling Frequency 1996-Present*
Continuous Water Quality[a]	Continuous	Continuous
Discrete Water Quality[b]	Monthly or semi-monthly	Monthly
Phytoplankton	Monthly or semi-monthly	Monthly
Zooplankton	Monthly – separate survey	Monthly – combined with discrete water quality
Benthos	Semi-annual or monthly	Monthly
Heavy metals and pesticides	Semi-annual	Discontinued

[a] The following constituents are monitored continuously at fixed, shore-based stations: air and water temperature, electrical conductivity, pH, dissolved oxygen, water stage, chlorophyll fluorescence, wind speed and direction, and solar irradiance. Not all constituents are monitored at all stations.

[b] The following constituents are measured at specific locations: air and water temperature, electrical conductivity, chloride concentration, dissolved oxygen, turbidity, secchi disk depth, suspended solids, inorganic and organic nitrogen concentration, inorganic phosphorus concentration, silica concentration, chlorophyll *a*, pH, water depth to 1% light level. Monitoring of air temperature, pH, and water depth to 1% light level was discontinued in 1995.

In its 32 years of existence, the EMP design has remained relatively unchanged. The greatest revisions came about in 1978 with the enactment of Water Right Decision 1485 and in 1996 after a major program review in 1995. The main goal of the 1995 revisions was to streamline the existing program for more efficient budget and resource allocation (Table 1). As a result, the number of discrete water quality monitoring stations was reduced from 26 to 11 sites, contaminants monitoring was discontinued, changes were made to the zooplankton and benthos monitoring elements, and substantial upgrades were made to vessel-based horizontal and vertical profile instrumentation.

II. Review Foundation

To initiate the EMP review, we worked to provide a solid foundation upon which to base the review. Here we list the key elements of this foundation, followed by brief explanations.

Establish a review Core Team: This is the first and most important step in conducting any sort of program review. The Core Team is responsible for completing the review, which ultimately comes down to taking the various bits of information and input received from a variety of groups and individuals and transforming them into meaningful results.

The EMP review Core Team included each of the DWR and USBR program managers for the monitoring program and one senior technical staff person each from DWR and USGS. A senior technical staff person from USBR joined the Core Team about midway through the review as the result of a new hire at USBR. This Core Team had several attributes that led to a high degree of effectiveness: (1) the team was small; (2) each team member had a strong, but not necessarily identical, interest in completing a successful review; (3) the team contained a mixture of program managers who had the authority to make programmatic decisions and very knowledgeable technical staff; and (4) the Core Team accepted full responsibility for completing the review.

Obtain a clear directive from management: IEP has a standing review policy for its monitoring programs, which provided the main directive for our review. However, this policy is general and does not provide clear guidance on the specific aspects of a review. For example, several IEP monitoring programs contain sub-elements or subject areas. Past reviews of some monitoring programs have only considered specific subject areas within the program rather than the entire program. In addition, some past reviews have emphasized the data and information aspects of the monitoring program and spent less time considering other factors such as sampling design, customer needs, or resource and staff allocations. In reality, the variety, complexity, and emphasis of different IEP monitoring programs means we cannot use exactly the same approach in all reviews. Thus, it was necessary that the Core Team work with management early on to develop a clear and specific directive detailing the scope of the EMP review.

The EMP contains four subject areas: environmental water quality, phytoplankton, zooplankton, and benthos. Comprehensive data analyses were fairly up-to-date with at least one comprehensive report on each element completed within the last 10 years; however, the program was three years behind in its annual reporting requirements. We also knew of several concerns related to sampling design and techniques, inadequate data management and dissemination infrastructure, a slow rate of transferring data to information, unclear or missing conceptual models, and a general lack of confidence that the EMP was monitoring the appropriate constituents at the proper spatial and temporal scales. Based on this knowledge, the Core Team and IEP management determined that a comprehensive programmatic review of the EMP was necessary.

Develop a clear goal for the review: The importance of having a clear statement of goals is well known. Also, questions like "what's your goal?" are usually among the first asked when meeting with people to discuss the review. Yet, we often make short shrift of this step, leading to unclear or inappropriate goals. A clear statement of goals should guide the review, help track and evaluate review progress, and focus review discussions.

Developing a clear goal for the EMP review was among the first tasks of the Core Team. Ultimately we developed the following goal:

> The goal of the review is to recommend a balanced, scientifically sound, implementable environmental monitoring program design to fulfill water right permit conditions and address

the needs of current and potential users identified during this review.

Determine expected products up front: Any review of an IEP monitoring program will result in at least one report describing the review process and results, which often include recommendations for change. In some cases, an intense period of data analysis and reporting precedes or is part of the actual review. Since the reviews largely rely on existing staff, IEP managers are generally forced into a situation that requires delaying work in order to complete new analyses and reports for the review. Building this part of the foundation comes down to matching expectations with reality. This requires meeting with key groups (managers, advisory groups, etc.) and key individuals (supervisors, program managers, and staff) to make sure everyone understands what products are required to meet the goals of the review and who will complete those products.

In the case of the EMP review, the Core Team met with IEP managers and the Science Advisory Group at the beginning of the review to determine the necessary products. Some IEP managers expected staff to complete new analyses and reports. The Core Team argued that several fairly recent comprehensive analyses of EMP data already existed, mainly in the form of technical reports. Although some of these reports were up to 10 years old, they provided a fairly complete understanding of the state of knowledge and the types of information available from the EMP. Ultimately, it was determined that a concise description of the EMP, including its history and regulatory basis, was essential information for this review[1], but that new data analyses were not.

Identify the major constraints upfront: From a practical standpoint, all monitoring programs are constrained by one or more factors. Limited funding and resources are often the ultimate constraint. Common constraints that are dependent on funding include geographic scope, sampling frequency, number of sampling sites, and number and type of constituents monitored. In addition, the strong desire to maintain data continuity is a constraint common to long-term monitoring programs. Preserving data continuity limits program redesign based on technical issues or program modifications to address changing management priorities and customer needs. Finally, some monitoring programs are legally required and any program modifications may have legal ramifications. Identifying these types of constraints early on in the review process provides reviewers with an appreciation for the limits to the types of changes possible.

The following constraints applied to the EMP review:

1. Total ongoing program costs would not increase. This did not preclude the potential redistribution of funds among subject areas or obtaining funds from outside sources to cover the cost of one-time expenditures (e.g., new equipment purchases).
2. Maintaining historical data continuity had priority over program redesign due to technical issues or changing customer needs.
3. The program would continue to fulfill the requirements set forth in D-1641.

Identify staff commitment: Completing an in-depth review of any IEP monitoring program is a substantial undertaking. For several years IEP has tried to complete these reviews as a task added to staff's existing workload. This has met with mixed success. The program manager or project supervisor is in the best position to establish this part of the review foundation. Program managers must work with their staff to estimate the number of staff and amount of effort necessary to complete the program review based on decisions about management directive, review goals, constraints, expected products, and timeline. Generally, at least one staff person will spend the majority of their time on the review, with an additional time commitment from the program manager(s) and other core staff. Often the issue comes down to securing a consistent amount of staff time over the full duration of the review. Underestimating necessary staff commitment or total review time undermines the ability to clarify staff commitment. The IEP management team can help program managers develop accurate estimates of the staff commitment necessary to complete a monitoring program review.

For the EMP review, the two program managers spent about 20% of their time on the review. They were assisted by three senior technical staff who spent between 10% and 80% of their time on the EMP review, as well as by other EMP personnel. In addition, the EMP review also relied on the work of ad hoc "subject area" teams (see below), with team leaders dedicating up to 50% of their

1. CA DWR. 2001. Background Information for the 2001 Review of the IEP Environmental Monitoring Program. Available at http://iep.water.ca.gov/emp/about%20the%20EMP.html

time over a five-month period and team members dedicating 5-10% of their time over the same period.

Establish a realistic timeline: As with determining the expected products, establishing a realistic timeline with key milestones comes down to matching expectations with reality. Generally, IEP management thinks in terms of one-year timelines for monitoring program reviews because they operate under a one-year program planning cycle. Yet the reality is that program complexities will often necessitate more than one year to complete a review. Setting a realistic timeline is highly dependent on decisions made for the other parts of the review foundation. The timeline may have to be revisited several times and adjusted as necessary throughout the course of the review.

Initially, the EMP review Core Team set a one-year timeline for completion of the review. Ultimately, however, it took 22 months to fully complete the review. Some of the delay was due to unrealistic estimates by the Core Team, while other delays were due to factors outside the control of the Core Team. For example, we grossly underestimated the amount of time necessary to complete the management review phase. In contrast, completing the independent review phase was delayed several months due to competing commitments for the time of the reviewers. Although delay in completing the written review products is a common occurrence in program reviews, this was not the case with the EMP review. The subject area reviews and synthesis reports were all completed within the original time allotted because of the tremendous efforts of the subject area teams and full dedication of Core Team time to complete the synthesis report.

III. Review Process

There are many levels of review possible for the types of monitoring programs within IEP. For the EMP review, the Core Team and IEP management determined a "program level" review was most appropriate. As such, the review examined all aspects of the monitoring program, including its overall structure, resource and staff allocation, funding allocation, underlying conceptual models, sampling design, data and information processes, customer needs, and the goals and objectives. Some aspects of the program were considered in greater detail than others, but we found this comprehensive approach provided the ability to identify more specific and meaningful recommendations for change.

In developing a review process for the EMP we wanted to ensure:

- An open and transparent process
- Substantial opportunity for local expert and key stakeholder input
- Inclusion of an independent technical review
- Clear and direct input from management
- Involvement of regulatory agency staff prior to formal submittal for regulatory approval. (Note: this last issue was EMP specific and does not apply to many of the IEP monitoring programs.)

To meet these multiple objectives, the EMP review process relied on a multi-tiered approach involving: (1) four subject area teams; (2) several open meetings, which allowed a broader base of participation; (3) the IEP Science Advisory Group; and (4) the EMP Core Team (Figure 1). Involvement and time commitment varied among the tiers throughout the review period (Figure 1). We further broke the review process down into a technical review phase followed by a management review phase.

The subject area teams (SATs) formed the backbone of the EMP review. The SATs were small, ad hoc teams composed of invited local experts and EMP staff. The main task of these teams was to complete a focused review of each EMP subject area (water quality, phytoplankton, zooplankton, and benthos). Although each team approached the subject review differently, the primary goal for all SATs was to produce a written subject area review based on a structured format. The SATs were asked to provide specific and prioritized recommendations for changes to the EMP, as well as recommendations and priorities for special studies needed to inform future decisions about the program. SAT members also participated in the open meetings, and SAT leaders assisted the Core Team in synthesizing the individual reports into a comprehensive review summary. The time commitment for the SATs was substantial in the early part of the review, but dropped off quickly after the first draft summary report was produced.

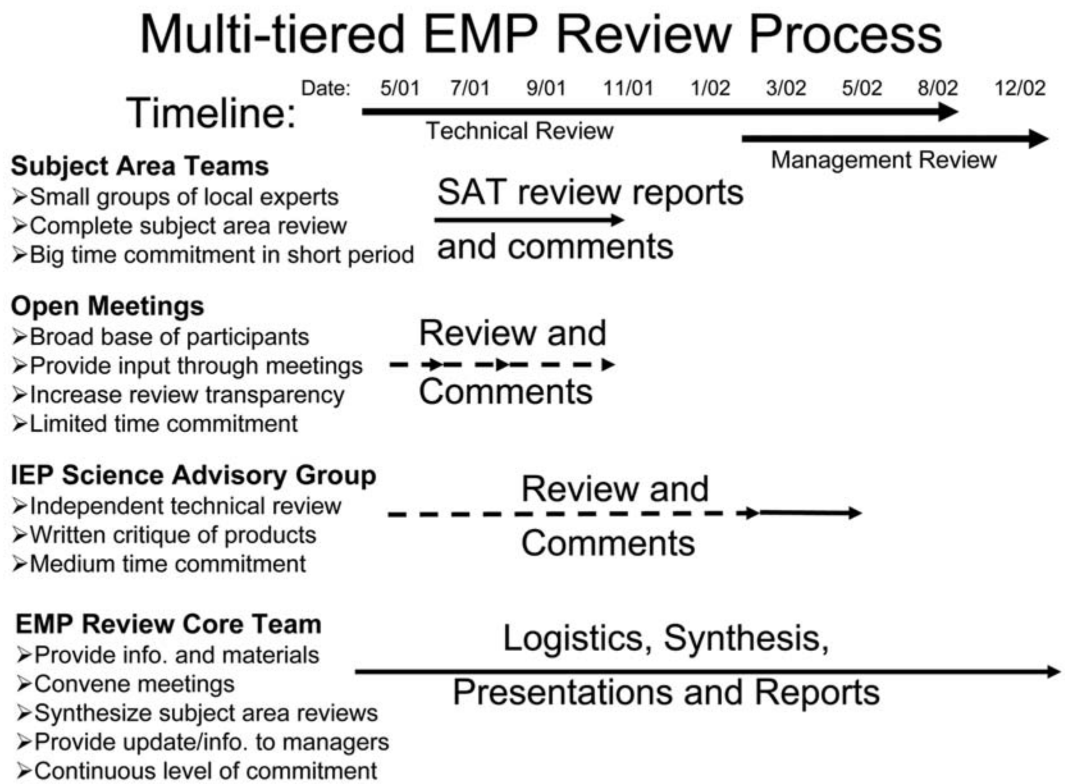

Figure 1 Diagram of the multi-tiered approach used in review of the EMP. Entities or forums listed on the left-hand side formed one of the four tiers. See text for a complete description of each tier. Solid lines constitute time spent directly involved in the review. Dashed lines constitute time spent indirectly or occasionally involved in the review.

Three open meetings where scheduled over the first seven months of the review. The open meetings provided a forum for information exchange and comments from a broader audience of stakeholders, agency staff, and the interested public. These meetings allowed for discussion of all aspects of the EMP and the review, but at a lower level of detail than the SAT review or independent technical review. Participants in the open meetings were expected to read the appropriate materials before the meeting and provide the majority of their input at the meeting (although we did provide means to send in comments anytime during the review process). The open meetings were an efficient way to communicate with a large number of interested individuals. We hired a professional facilitator for these meetings to provide a respectful, productive, and non-threatening environment. EMP staff also prepared poster summaries for each EMP subject area, which served as a great information resource at the meetings. The open meetings and establishment of a Web page with information and materials provided an effective way to maintain a transparent review.

The IEP Science Advisory Group was asked to provide an independent technical review of the individual SAT reports and the EMP review synthesis report. Up to three Science Advisory Group members also participated in the open meetings, providing key guidance in the structure and scope of the review. The group also brought in three additional scientists with expertise specific to EMP subject areas to complete this review. The Core Team participated in a one-day meeting with the Science Advisory Group to provide specific information about the EMP and the review results. Group members were also provided with relevant written materials in advance of the meeting. The Science Advisory Group was free to comment on any aspect of the program or the review, but in particular we asked the group to consider and comment on: (1) program design (current and proposed), (2) information synthesis and subject area integration, and (3) resource allocation. We also asked the group to be as specific as possible in any recommendations it made. The Science Advisory Group provided a written report to the Core Team about one month after our meeting. Overall, the Science Advisory Group contributions were vital to the success of the EMP review. Early and continued involvement by some advisory group members, clear communication of expectations, and timely response to the Science Advisory Groupís review were all key to this success. We are certain that any future review of an IEP monitoring program will greatly benefit from early and thoughtful interaction with the Science Advisory Group.

Core EMP staff from DWR, USBR, and USGS worked across all review levels. The Core Team provided all information and background materials for the review. The team convened the open meetings with the help of a facilitator. Three of the Core Team members participated in the SATs. Team members were responsible for synthesizing review products into a single report, as well as providing the many progress reports requested throughout the review. The Core Team also completed the management-level review, which included briefings for key stakeholders. Finally, the Core Team prepared a formal request to the SWRCB for modifications to the D-1641 condition specifying the EMP design.

Overall, this multi-tiered review process required substantial effort. Yet, it was a great success because we were able to achieve all of the review objectives and reap some unexpected benefits, such as greater recognition for the EMP and reinvigorated staff enthusiasm.

IV. Expect the Unexpected

The staff involved in any IEP monitoring program will have a good sense of program strengths and limitations even before the review is started. The review process is a good opportunity to critically evaluate these perceptions and address some of the perceived limitations. We identified several limitations at the beginning of the EMP review, including:

- Limited staff time and expertise for data analysis
- Ineffective data management processes
- Limited integration among subject areas

These limitations were also identified in the Subject Area Team and Science Advisory Group reports, reinforcing the significance of these limitations. However, several unexpected events occurred during the course of the review that allowed us to address these limitations even before the review was completed. In contrast, some events occurred over the course of the review that created some new and continuing challenges for the EMP.

On the positive side, the EMP was successful in obtaining a position from the CALFED Science Program that was dedicated to efforts aimed at improving data management and data to information transfer. The departure of three existing staff during the review also resulted in DWR and USBR hiring three staff scientists with PhDs in various fields of aquatic ecology, increasing the “intellectual investment” in the program.

The review reinvigorated staff interest and commitment to the EMP. Existing EMP staff became very engaged in the review, contributing substantially to the information and historical knowledge base needed to complete the review. This staff involvement was instrumental in the formation of the IEP Water Quality Project Work Team, which continues to meet and guide the EMP to this day.

Although several positive unexpected events occurred during the EMP review, some unexpected challenges also occurred. We grossly underestimated the time necessary to complete the management level review. This was due in part to the fact that IEP does not have a well-defined process for dealing with the results of technical program reviews at the management levels of IEP and the individual agencies. In addition, the legally mandated nature of the EMP increased the number of management review levels we had to navigate. The extra time spent in the management review phase was beneficial, and hopefully any future reviews of the EMP can benefit from our experiences.

At this time, the state budget crisis is probably the greatest challenge to implementing recommended changes to the EMP. Delays in passing the state budget, budget cuts, and a prolonged hiring freeze will undoubtedly affect the timeline for implementation of the approved changes. Further, reductions in IEP funding will affect the potential to fund special studies needed to determine the best methods for making approved changes and confirming the results of any changes made. These serious budgetary constraints will require creative solutions by program managers and staff to effect meaningful changes to the EMP.

V. The Importance and Utility of Review Products

Preparation of review products is a key part of any IEP monitoring program review. Typically, there is a report that contains a description of the review and any recommended changes. Other products might include reports of data analyses and synthesis. Over the course of the EMP review several products were produced that we expect to have utility beyond the review.

Specific statements of EMP goals, objectives, and questions: The fact that the EMP lacked clear program aims was a major concern identified in the Science Advisory Group review. General goals for the EMP are listed in the water right decision, but beyond this we did not find any specific statements of program aims or goals. As a result, the Core Team spent substantial time developing more specific objectives and questions, which build on the more general goals stated in D-1641. This was not a trivial matter, even for a small, but motivated, Core Team. Guidance from the Science Advisory Group was critical to our efforts, and ultimately we were able to develop a set of realistic and specific objectives. Questions were also developed to focus future reporting, but we expect the questions will change as new issues and management priorities emerge.

Conceptual models: The Water Quality SAT devoted a great deal of effort to developing a conceptual model that describes the underlying physical processes occurring in the upper estuary and how those physical processes affect water quality. The other SATs were able to use this model in understanding how physical processes affect phytoplankton, zooplankton, and benthos ecology. This was the first time a comprehensive set of conceptual models has been developed for the EMP, and these models served as the foundation for recommended changes in the EMP sampling design. We expect these models will be revisited as the program moves forward and particularly during the next EMP review.

Assessment of customer needs: At the first open meeting, one of the members of the Science Advisory Group urged us to include an evaluation of customer needs during the EMP review. We developed a table for use in each subject area that asked for customer identification and the met and unmet needs of these customers. Although the results were qualitative, they were very useful in determining the most important attributes and the most critical unmet needs of the EMP from the "customers" perspective. Results from this assessment were used in developing recommendations for changes to the monitoring program, as well as specific goals and objectives.

Specific recommendations for changes to the EMP: In reviewing the history of the EMP it was quite clear that many past recommendations for changes to the monitoring program were never implemented because the recommendations were too vague or general. As a result, the Core Team continually pressed for specific recommendations from all parties. In addition, the Core Team asked the SATs to prioritize any recommendations provided in the subject area reviews, and the Core Team developed an overall list of prioritized recommendations in the synthesis report. We are hopeful that these two features--specificity and prioritization--will increase the likelihood that recommended program changes will be implemented.

Specific recommendations for EMP special studies: Review of the EMP history also confirmed that the EMP has never had a special studies plan. Through the EMP review we came to recognize that special studies to improve monitoring and better understand monitoring results are an essential part of comprehensive monitoring programs like the EMP. Many of the recommended changes require focused special studies to determine the exact methods of implementation and verify the results of any changes. In addition, new technologies in water quality monitoring, data acquisition, and data transfer continue to emerge; all of which must receive some testing before making decisions on implementation. And finally, monitoring will always generate new questions and hypotheses that can only be tested through applied research. Information gained through this research can tell us if we are monitoring the right things the right way. Thus, the Core Team again turned to the SATs and asked for prioritized recommendations for special studies. In the phytoplankton and benthos subject areas, virtually all of the recommendations revolved around the need to complete focused special studies to refine sampling and analytical strategies and clarify the meaning of the data. However, during discussions with management about the EMP review, it became clear to us that IEP does not have an effective means of integrating ongoing monitoring with special studies intended to directly inform the monitoring program. This is a pressing issue for IEP because each monitoring program review will undoubtedly generate a list of needed special studies.

VI. Conclusions

1. An in-depth review of any IEP monitoring program is a staff intensive and time-consuming effort. In addition, we found that some expenditure above ongoing program costs is necessary for a successful review. Throughout the EMP review, the Core Team had to continually work to resist succumbing to one of Murphyís Laws: “There is never enough time to do it right the first time, but there is always time to do it over again.” IEP must carefully consider staff, time, and funding commitments when making decisions that obligate a program to review.

2. A strong commitment to implementing the recommended monitoring program changes is essential. Substantial effort by many people is required to complete meaningful program reviews. Failure to implement program changes inhibits program progress and jeopardizes the commitment to future IEP monitoring program reviews.

3. We realized many benefits to completing an open, multi-level program review beyond the specific recommendations for changes to the monitoring program. The chief benefits include: (a) reinvigorating staff interest in the program and building staff respect, (b) increasing public and agency knowledge about the monitoring program, (c) developing a robust conceptual basis for the sampling design, and (d) developing a prioritized special studies plan.

4. Involvement of the independent IEP Science Advisory Group was critical to the success of the EMP review. Early and continued involvement by some advisory group members, clear communication of expectations, and timely response to the advisory group’s recommendations were all key to this success.

VII. Acknowledgements

The EMP review and the contents of this article would not have been possible without the participation of the other Core Team members: Jon Burau (USGS), Ken Lentz (USBR), and Erwin Van Nieuwenhuyse (USBR).

This article is dedicated to Kitty (Katherine) Triboli of DWR. Much of the success the EMP enjoys today is due to her unwavering support and dedication to the EMP over the last three decades. Kitty, we wish you all the best in your future endeavors.

California Bay-Delta Authority[1] Activities

California Bay-Delta Authority: Science Symposium on Environmental and Ecological Effects of Proposed Long-term Water Project Operations

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On June 19-20, 2003, in Sacramento, the California Bay-Delta Authority (CBDA) Science Program convened the second in its series of symposia and workshops on water project operations and environmental management in the San Francisco Estuary and watershed. The first workshop, held on April 22-23, 2002, in Sacramento California, is summarized in a Science Program report available at http://science.calwater.ca.gov/pdf/Workshop_Operations_Summary_April21-22-02.pdf.

The June 2003 symposium brought together more than 200 managers, scientists, and stakeholders to present and discuss information related to the environmental and ecological effects of proposed long-term operations of the Central Valley Project (CVP) and State Water Project (SWP). In this symposium, participants considered key science issues associated with the proposed long-term operations. The goals for this symposium were to:

1. Provide a forum for a balanced open discussion of proposed CVP and SWP operations, water management strategies, and the consequences to fish species of concern in the Delta and upstream project areas.

2. Help the public, stakeholders, and the agencies developing the biological opinions for CVP and SWP operations, pursue a common understanding of the state of knowledge and critical uncertainties associated with evaluating the implications of proposed water project operations and water management strategies in the Delta and upstream project areas.

3. Provide managers and policy makers a synopsis of the "state of knowledge and uncertainties" for some of the most important intersections between policy and science with respect to proposed changes in water project operations.

An inter-agency organizing committee developed the symposium agenda around several scientific issues related to water project operations:

- Upstream flow fluctuations and barriers to fish migration.

- Understanding Bay-Delta processes, and sources of fish mortality in the Delta.

- The effects of Delta inflow and water project operations on fish mortality: What have we learned from the Vernalis Adaptive Management Program (VAMP) and Delta Cross Channel (DCC) studies?

The symposium began with policy perspectives provided by key stakeholders and state and federal representatives. Presentations to discuss the current state of knowledge followed from agency, stakeholder, and academic scientists. The agenda included audience question and answer sessions, as well as panel discussions of the technical information and its implications for managers. Here we provide a brief summary of some of the major findings.

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1. Formerly CALFED. Effective January 1, 2003 a new state agency has formally assumed responsibility for overseeing implementation of the Bay-Delta Program. The California Bay-Delta Authority, established by legislation enacted in 2002, provides a permanent governance structure for the collaborative state-federal effort that began in 1994.

   The Authority was established by enactment of Senate Bill 1653 (Costa) of 2002. The legislation calls for the Authority to sunset on January 1, 2006, unless federal legislation has been enacted authorizing the participation of appropriate federal agencies in the Authority.

Upstream flow fluctuations and barriers to fish migration

Upstream fluctuations in flow (duration, magnitude, and frequency) resulting from reservoir operations can affect salmon spawning success, embryo development, hatching success, and juvenile rearing. These direct biological consequences have all been measured and quantified, but linking these to population-level impacts, especially across a range of hydrological conditions, requires additional investigation and analysis.

Operation of the Red Bluff Diversion Dam (RBDD) can present a substantial barrier to fish migration. Present operations (gates closed 4 months and gates open 8 months of each calendar year) have removed RBDD as a migration barrier to winter-run Chinook salmon; however, spring-run Chinook salmon adults reach RBDD at a time when the gates are closed. Thus, the effects on fish immigration depend on the basic timing of the runs relative to RBDD gate operations. Present operations of RBDD have substantially reduced the sustained accumulation of predatory fish, thereby reducing the mortality of young salmon migrating past RBDD. The most direct management options to address remaining RBDD concerns involve enlarging the fish ladders or completing substantial modifications to the water diversion structures upstream of RBDD to shorten the period of gate-in operations.

Understanding Bay-Delta processes, and sources of fish mortality in the Delta

Our understanding of Delta hydrodynamics and ecological interactions (open-water processes) has advanced tremendously in the last decade. Researchers now have a much better understanding of how tidal forces shape the physical environment of the estuary and the affects this environment can have on the distribution of various organisms. The more we learn, however, the more we come to realize how complex the estuary is. Continued process-based studies, coupled with monitoring of long-term trends and analyses of these data in the context of understanding the consequences of water operations, will help to further reduce the uncertainties of how water project operations affect physical processes in the Delta and the subsequent abundance and distribution of living resources.

Mortality is an important ecological process that can affect population size. Studies of fish mortality in the Delta have generally considered total mortality (mortality from all sources) or direct CVP and SWP mortality (mortality resulting from entrainment in water project diversions). Yet, conceptually at least, we also hear about other types of fish mortality, including non-project anthropogenic mortality (e.g., fish mortality due to entrainment in delta agricultural diversions or fishing) and indirect mortality (e.g., increases in natural and non-project anthropogenic mortality arising from water project induced changes in Delta hydraulics or water quality). Quantifying the effects of any type of fish mortality is difficult, especially in the context of population-level effects. But quantifying the population-level effects of fish mortality is an important step for comparing the potential effectiveness of different management actions. Further, the current regulatory framework and management level responses often require quantification of the various types of mortality to assess impacts and prescribe mitigation. We may be able to enhance our approaches by thinking about how to manage and reduce total fish mortality, rather than continuing to try and manage various types of mortality independently.

Relationships emerging from recent data and analyses may provide additional restoration opportunities for species of concern. Juvenile Chinook salmon appear most vulnerable to exports when actively emigrating through the Delta. Direct CVP and SWP entrainment mortality remains a management concern, but the data suggest direct loss is often small. Splittail analysis and modeling of abundance and distribution data show that this fish is highly resilient, but that long-term success of the species depends on seasonal floodplain inundation to promote successful spawning. For delta smelt population success, four key issues emerge from the current conceptual model: (1) water exports, (2) toxic chemicals, (3) food web effects, and (4) temperature window for recruitment. Evidence suggests that direct mortality from CVP and SWP entrainment may be high enough in some years to reduce the population size of adult spawners. Similarly, toxic chemicals and food limitations may result in higher mortality rates of delta smelt in some years.

The effects of Delta inflow and water project operations on fish mortality: What have we learned from the Vernalis Adaptive Management Program (VAMP) and Delta Cross Channel (DCC) studies?

VAMP and DCC investigations examine relationships between Delta inflows, water project operations, and young salmon survival in the Delta. Although the studies differ in their experimental designs, both studies contribute scientific information important to future opportunities and management actions. VAMP and DCC research both show that fish are affected on all flow variance time scales (hourly to seasonal). The VAMP studies show that San Joaquin River quantity affects water quality, but determining smolt survival relative to flow requires additional investigation of various flow regimes under this 12-year study. The DCC studies have found that local velocity profiles and time of day drive fish distribution and catch.

The VAMP and DCC studies offer new insights and tools for examining how physical processes affect fish survival in the Delta. For example, in river bends and channel junctions, fish move with the velocity vectors (current structure), not simply the bulk flow discharge. The implication for managers is that understanding water velocity structure within bends and junctions and the interactions with fish behavior may lead to novel solutions to minimize impacts of existing and proposed water operation facilities. Further, integrating contaminant research into multidisciplinary studies like VAMP and DCC can also help to reduce the uncertainty associated with through-Delta salmon survival through the application of innovative tools and research strategies.

Next steps

Science Program staff is preparing a June 2003 symposium written summary report with a target completion date of September 2003. The report will be available, along with past workshop reports and future workshop dates, from the new Science Program website at http://science.calwater.ca.gov.

Additional Science Program workshops in July (Chinook salmon) and August (delta smelt) will consider new information on modeling and the population biology of these fish, and consider how actions under the EWA program protect these fish. A workshop in October will include a technical review of the EWA and further discussion of specific issues related to water project operations and the associated environmental impacts. For additional information on this workshop series, please visit http://science.calwater.ca.gov/workshop/workshop.shtml.

Acknowledgements

The Science Program extends special thanks and acknowledgements to our inter-agency organizing committee and the more than 20 presenters listed in the agenda at http://science.calwater.ca.gov/pdf/ScienceSymposium-Agenda.pdf.

Publications in Print

Recent Research Published in the Open Literature

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This has been another busy year for San Francisco Estuary researchers, with new publications in a diverse range of journals. The most recent publications by IEP-affiliated scientists include the following. Note that some of these do not appear in the "official" IEP Bibliography (Rivard and Sommer, this issue) because they did not meet our criteria for IEP funding, staff, or data. However, all of the studies represent impressive additions to the growing body of literature about the estuary.

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The IEP Bibliography: Journal Articles and Books

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The following reference list represents our efforts to compile an "official" IEP bibliography for journal articles and books that have been produced through the program's efforts. The idea was to develop a comprehensive list of peer-reviewed papers to provide a track record of our progress, and as a reference list for the major scientific issues and findings for the San Francisco Estuary. One of our biggest hurdles was to define the criteria that we would use to identify papers for which IEP could claim some credit. These issues were reviewed by the IEP Management Team, who decided that it would be appropriate to include any peer-reviewed paper or book chapter that met one of the following criteria:

1. At least some IEP funding was used for the research
2. Research that relied on IEP samples
3. A study performed using a substantial amount of IEP data
4. The project was an official IEP "Program Element" (e.g., IEP staff, study plan and review process)
5. Papers were published as part of an IEP-sponsored volume (e.g., DFG Fish Bulletin Salmon Symposium)
6. A paper co-authored by an IEP staff member.
7. Work preceding the formal formation of the IEP that focused on the evaluation of potential water project impacts or the collection of pre-project data.

Based on these criteria, many potential entries were excluded. First, we did not include IEP Technical Reports or US Geological Survey (USGS) file reports because they did not meet our requirement for peer-reviewed journal or book contributions. We excluded much of the important work from key IEP member agencies such as USGS, University of California, Davis (UCD) and Department of Fish and Game (DFG) for projects that were entirely funded by outside programs. Similarly, most CALFED-funded projects were not included in the list unless the work was performed as part of an IEP program (e.g., Yolo Bypass and Breach studies). DFG articles on the Delta from the 1960s and 1970s preceded the formation of IEP, but were included because the work focused on the collection of pre-project data or collected early data for ongoing IEP surveys. Note that this summary is intended as a work in progress that will be updated regularly and posted on the IEP website (http://www.iep.water.ca.gov/report). We encourage everyone to send us suggestions for future revisions.

The following papers met at least one of our bibliographic criteria. Studies in which the only criterion met was number 3 are identified after the citation ("USED IEP DATA").

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